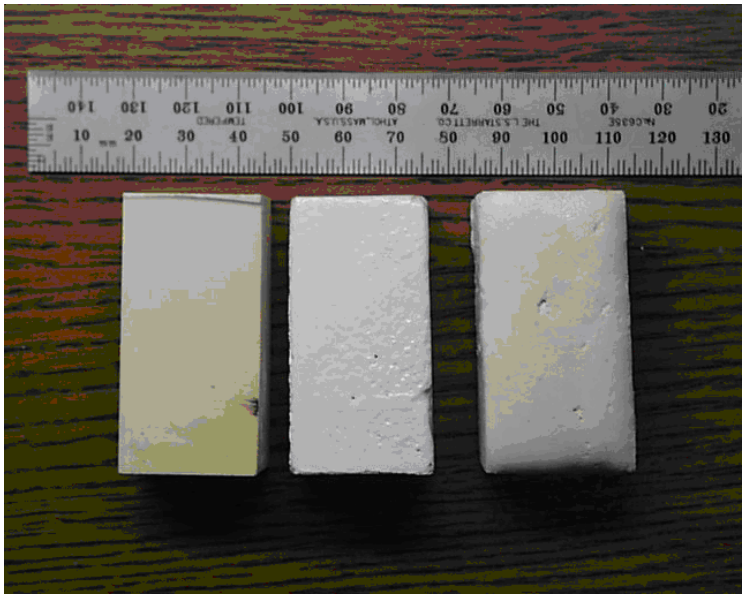
Industrial Technologies Program

High Density Infrared Surface Treatments of Refractories

Innovative Surface Processing Will Reduce the Penetration, Wetting, and Corrosion Behavior of Refractories

Refractory materials play a crucial role in all energy-intensive industries and are truly a crosscutting technology for the Industries of the Future (IOF). One of the major mechanisms for the degradation of refractories and a general decrease in their performance has been the penetration and corrosion by molten metals or glass. Methods, techniques, and materials that would reduce the penetration, wetting and corrosive chemistry would significantly improve refractory performance and also the quality of the processed liquid, be it metal or glass.

As a method to greatly improve refractory performance, the use of high density infrared (HDI) heating to surface treat refractories was investigated. The project was a joint effort between Oak Ridge National Laboratory and the University of Missouri-Rolla. HDI is capable of heating the near-surface region of materials to very high temperatures where sintering, diffusion, and melting can occur. The intended benefits of HDI processing of refractories were to: (1) reduce surface porosity (by essentially sealing the surface to prevent liquid penetration), (2) allow surface chemistry changes by bonding an adherent coating onto the underlying refractory (that would inhibit wetting and/or improve corrosion), and (3) produce non-contact refractories with high emissivity surface coatings.



Visual appearance of fused-cast alumina-zirconia-silica (AZS) refractory before and after HDI treatment. Left to right: as-received sample; zirconia-painted sample prior to HDI treatment; after HDI treatment. Surface melting and bonding of the coating was evident.

Benefits for Our Industry and Our Nation

The potential benefits of improved refractories include:

- *Total cost savings of $145 million/ year in the aluminum and glass industries by the year 2020.*
- *Total energy savings of 30 TBtu/year in the aluminum and glass industries by the year 2020.*
- *Reduced emissions of both CO_2 and NO_x.*

Applications in Our Nation's Industry

Ceramic refractories are widely found in high-temperature, chemically demanding applications. These materials are critical construction materials for energy-intensive industries. Refractories are truly a cross cutting technology that is common to multiple industries:

- Aluminum
- Chemicals
- Forest Products
- Glass
- Metalcasting
- Steel

Project Description

The goals of the project were to: (1) reduce open surface porosity on commercially available refractories and demonstrate improved penetration resistance; (2) fabricate corrosion-resistant surface layers on refractories by selective sintering of secondary layers and show improved corrosion behavior; and (3) produce non-contact refractories with high emissivity surface coatings.

Barriers

- Refractory materials have remained unchanged for many years, and most current materials are reaching their ultimate performance limits
- Penetration and corrosion of refractories are two major mechanisms for their degradation and decrease in performance
- Advanced ceramics could make improvements in refractory performance, but their cost has prohibited their wide-spread use

Pathways

The project was done in a series of tasks over a three-year period:

Task 1: Demonstrate ability to reduce open surface porosity on commercially available refractories and evaluate the corrosion behavior.

Task 2: Fabricate corrosion-resistant surface layers on refractories by either diffusion coating or selective sintering of secondary layers.

Task 3: Produce refractories having high emissivity surface coatings (in addition to low porosity and high corrosion resistance).

The HDI technology is relatively new to the materials processing area. The HDI processing facility at ORNL utilizes a unique technology to produce extremely high-power densities of 3.5 kW/cm^2 with a single lamp, which is currently the most powerful one in the world.

Results

- The HDI treatment of commercial refractories to reduce surface porosity showed that the surface properties can be altered
- Corrosion testing showed the HDI treatment was effective in reducing penetration by molten copper
- It was demonstrated that zirconia-rich coatings could be formed on the surfaces of alumina zirconia silicate (AZS) refractories using HDI thermal treatments
- Corrosion testing in a container of glass-$NaCO_3$ mixture at 1400°C showed the zirconia-rich coatings help form boundary layers on the surfaces and reduced dissolution of the refractory
- High emissivity coatings were produced using the HDI system
- The results showed that the surface coatings could alter the emissivity of fibrous ceramics

Commercialization

This project was explorative in nature to determine the feasibility of various surface modifications of refractories. The results demonstrating improved refractory performance by surface treating with HDI heating were of interest to several refractory, glass and metal melting industries. However, there were several hurdles that prevented commercial implementation of the technology. The most significant was cost (both capital and operating). As the use of HDI increases in several other areas, the capital costs will decrease and will become more available for use in treating refractories. Operating costs were also an issue mainly because refractories are a commodity product and the profit margins are small. The large volumes of materials used offset the small margins. Thus, any increase in manufacturing has a significant impact on the profitability of the materials.

Project Partners

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University of Missouri - Rolla
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Magneco-Metrel, Inc.
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Allvac, Inc.
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A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

U.S. Department of Energy
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